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Open-File Report 2009–1192

U.S. Department of the Interior
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Conversion Factors

Multiply	By	To obtain
inch (in.)	25.4	millimeter (mm)
liter (L)	0.2642	gallon (gal)
cubic foot per second (ft3/s)	0.02832	cubic meter per second (m3/s)

Temperature in degrees Celsius (°C) may be converted to degrees Fahrenheit (°F) as follows:

°F=(1.8×°C)+32

Bacteria concentrations are given in colony-forming units per 100 milliliters (CFU/100 mL).

Relations Between Environmental and Water-Quality Variables and *Escherichia coli* in the Cuyahoga River With Emphasis on Turbidity as a Predictor of Recreational Water Quality, Cuyahoga Valley National Park, Ohio, 2008

By Amie M.G. Brady[1] and Meg B. Plona[2]

Abstract

During the recreational season of 2008 (May through August), a regression model relating turbidity to concentrations of *Escherichia coli* (*E. coli*) was used to predict recreational water quality in the Cuyahoga River at the historical community of Jaite, within the present city of Brecksville, Ohio, a site centrally located within Cuyahoga Valley National Park. Samples were collected three days per week at Jaite and at three other sites on the river. Concentrations of *E. coli* were determined and compared to environmental and water-quality measures and to concentrations predicted with a regression model. Linear relations between *E. coli* concentrations and turbidity, gage height, and rainfall were statistically significant for Jaite. Relations between *E. coli* concentrations and turbidity were statistically significant for the three additional sites, and relations between *E. coli* concentrations and gage height were significant at the two sites where gage-height data were available. The turbidity model correctly predicted concentrations of *E. coli* above or below Ohio's single-sample standard for primary-contact recreation for 77 percent of samples collected at Jaite.

Introduction

Traditional culture-based methods for determining recreational water quality with respect to *Escherichia coli* (*E. coli*) concentrations can take 18 hours or longer to obtain results. Consequently, information about current recreational water quality is based on conditions that may no longer be relevant. Decisions based on such information can result in either unneeded no-swimming alerts and lost recreational opportunities or—more unfavorably—unintended exposure for recreationists to waters that do not meet recreational standards if an alert is warranted but not issued. At Cuyahoga Valley National Park (CVNP), which is in northeastern Ohio, park managers discourage use of the Cuyahoga River for recreation because water-quality conditions can change so quickly.

The Ohio Environmental Protection Agency assigns minimum water-quality requirements for all state surface waters on the basis of use designations. Within CVNP, the Cuyahoga River has been assigned a use designation of primary-contact recreation, meaning the waters are capable of supporting full-body-contact recreation activities such as wading, swimming, and canoeing (Ohio Environmental Protection Agency, 2008). The specific numeric criterion for *E. coli* for this use designation in a single sample is 298 colony-forming units per 100 milliliters (CFU/100 mL). This water-quality standard (WQS) was used as a benchmark to evaluate recreational water quality in this study.

Regression models used to predict same-day recreational water quality have been shown to produce accurate predictions for coastal beaches (Francy and Darner, 2007; Francy and others, 2003; Nevers and Whitman, 2006; Nevers and others, 2007) and rivers (U.S. Geological Survey BacteriALERT Program, *http://ga2.er.usgs.gov/bacteria/default.cfm*). During previous studies within the park, the U.S. Geological Survey (USGS), in cooperation with CVNP, collected water-quality data to develop a regression model to predict recreational water quality of the river at one site centrally located within the park: the historical community of Jaite, within the present city of Brecksville, Ohio (fig. 1) (Brady and others, 2009). The Jaite model correctly predicted exceedances and non-exceedances of the WQS in 77 percent of samples collected at this site during the recreational seasons (May through August) of 2004–7.

In 2008, the USGS, in cooperation with CVNP and the Ohio Lake Erie Commission, did a study to validate the Jaite regression model developed from data collected during 2004 through 2007 and examine other water-quality variables that may be of use for predicting recreational water quality in

[1]U.S. Geological Survey.

[2]Cuyahoga Valley National Park.

the Cuyahoga River. Results of the culture-based method of determining *E. coli* concentrations were compared to environmental and water-quality variables at Jaite and at three other sampling sites near or within CVNP. In addition, for the Jaite site, results of the culture-based method were compared to the predicted *E. coli* concentrations from the regression model. *E. coli* concentrations measured at the three other sites were compared to predicted concentrations at Jaite to determine whether the model could also predict *E. coli* concentrations elsewhere in the river. This report summarizes the data collected from the 2008 study.

Methods

Water samples were collected from the Cuyahoga River at Jaite, the site studied by Brady and others (2009), three days per week from June through August 2008. Three other sites (table 1, fig. 1) were sampled along with sampling at Jaite at various times during the recreational season. Old Portage, a site just upstream from the park and from a municipal wastewater-treatment facility near Bath, Ohio, was sampled from mid-June through mid-July. Sampling at Old Portage was abandoned in favor of focusing on a stretch of the river more often frequented by recreationists—between Lock 29 and Independence (Lisa Petit, Cuyahoga Valley National Park, oral commun., 2008). Independence, a site near the downstream edge of the park, was sampled from mid-July through August. Lock 29 in Peninsula, Ohio, a site several miles downstream from the municipal wastewater-treatment facility and upstream from Jaite, was sampled from late July through August. Within the park, the Cuyahoga River flows north into Lake Erie. Further site information can be found in table 1.

Samples were collected from a bridge by using a weighted-bottle sampler fitted with a sterile 1-L bottle at one location near the center of flow (U.S Geological Survey, 2006). The weighted sampler was submerged several inches and the bottles were allowed to fill to within 2 in. of the top. The bottles were then capped and placed on ice in a cooler until analyses were performed.

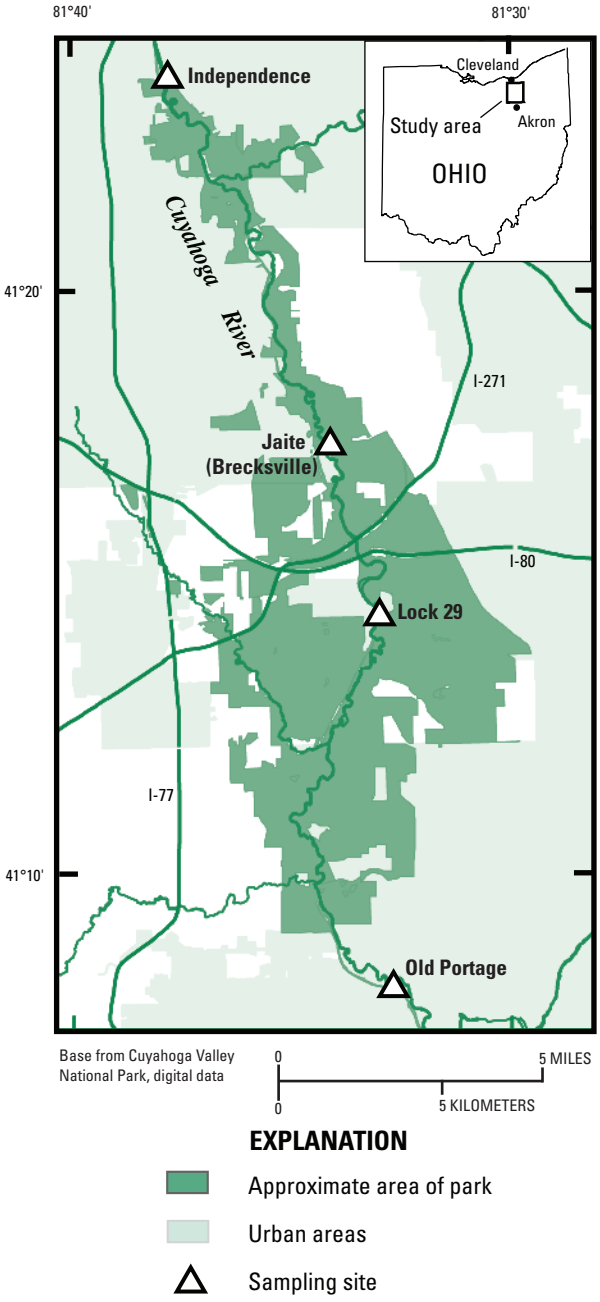

Figure 1. Cuyahoga Valley National Park, Ohio, and water-quality sampling sites during the recreational season (May through August) of 2008.

Sample Analyses and Environmental Data Collection

Determination of *E. coli* concentrations always began within 6 hours of sample collection in accordance with U.S. Environmental Protection Agency Method 1603 (U.S. Environmental Protection Agency, 2006). Aliquots of sample were filtered through membrane filters, and the filters were transferred to modified mTEC agar and incubated for 2 hours at 35°C and then 22 hours at 44.5°C. Magenta-colored colonies visible after incubation were counted as *E. coli* and reported as colony-forming units per 100 milliliters.

Other environmental parameters/variables were measured in addition to *E. coli* concentrations. These included water level at time of sampling (used to estimate streamflow), turbidity, and total rainfall in the 24 hours prior to sample collection. Water level was measured by means of a USGS streamgage (at Old Portage and Independence) or a manual, steel-tape measurement from a known elevation on the bridge to the surface of the water (at Jaite). Gage height was not measured at

Table 1. Cuyahoga River water-quality sampling sites during the recreational season (May through August) of 2008 from the most upstream to the most downstream locations, Cuyahoga Valley National Park, Ohio.

[CVNP, Cuyahoga Valley National Park]

Site name	USGS station identification number	Short description of location
Old Portage	04206000	Just upstream from CVNP at North Portage Path, Akron, Ohio.
Lock 29	411433081330000	Just downstream from Peninsula on the Ohio and Erie Canal Towpath Trail near Lock 29 Trailhead, Peninsula, Ohio.
Jaite	411747081341300	Centrally located within CVNP at Vaughn Road, Brecksville, Ohio
Independence	04208000	At the downstream boundary of CVNP at Old Rockside Road, Independence, Ohio

Lock 29 because this was a new site selected for this project, and no historical streamflow information was available. Turbidity was determined in the laboratory with a portable turbidimeter and was reported in nephelometric turbidity ratio units (NTRU). Local rainfall totals for the previous 24 hours were obtained from the Ohio Emergency Management Agency's Automated Flood Warning System (*http://www.afws.net*).

Quality-control checks were performed onsite monthly to ensure that sample collection and analyses were done according to protocols. In addition, filter blanks, replicates, and field blanks (described in detail by Francy and others, 2008) were collected and analyzed daily, weekly, and monthly, respectively, throughout the study. Filter blanks consist of sterile buffer water filtered prior to sample processing and then analyzed in the same manner as environmental samples to ensure sterility of equipment and buffer. A replicate is a second sample collected and processed with the regular sample to assess analytical and sampling variability. A field blank is an aliquot of sterile buffer water that is transferred into a sterile sample bottle in the field and then analyzed in the same manner as environmental samples to evaluate proper handling of samples. No quality-control problems were identified during quality-control checks. No bacterial growth was observed on the filter blanks or on filters plated from the field blanks. Variability, defined as the absolute value of the difference between $\log_{10}$-transformed replicate pair concentrations divided by the average of the $\log_{10}$-transformed concentrations, ranged from 1 to 4 percent.

Statistical Analyses

Correlation analysis and scatterplots were used to examine the relations between *E. coli* concentrations and turbidity, total rainfall, and gage height. A linear correlation coefficient (Pearson's r) was used to determine the degree to which *E. coli* concentration was linearly related to covariates. The more the coefficient differs from 1 or -1, the weaker the relation. Simple linear regression analysis was used to estimate *E. coli* concentrations in the river on the basis of one explanatory variable. The level of significance for statistical tests was set at $\alpha = 0.05$ for this report.

Correlations Between *E. coli* Concentrations and Environmental Variables

Site-specific summary statistics for *E. coli* concentrations are listed in table 2. Higher average concentrations of *E. coli* were observed at the Old Portage and Jaite sites than at the Lock 29 and Independence sites. This may be because the other two sites were not sampled until later in the summer, after the higher concentrations were observed at Old Portage and Jaite (fig. 2). Also, samples were collected during three high-streamflow events (daily mean streamflow greater

Table 2. Summary statistics for Escherichia coli concentrations in the Cuyahoga River during the recreational season (May through August) of 2008, Cuyahoga Valley National Park, Ohio.

[CFU/100 mL, colony-forming units per 100 milliliters]

Site name	Number of samples	*Escherichia coli*, in CFU/100 mL			
		Minimum	Median	Maximum	Average
Old Portage	12	130	420	10,000	2,000
Lock 29	8	77	330	930	430
Jaite	31	51	390	34,000	2,900
Independence	13	78	200	800	290

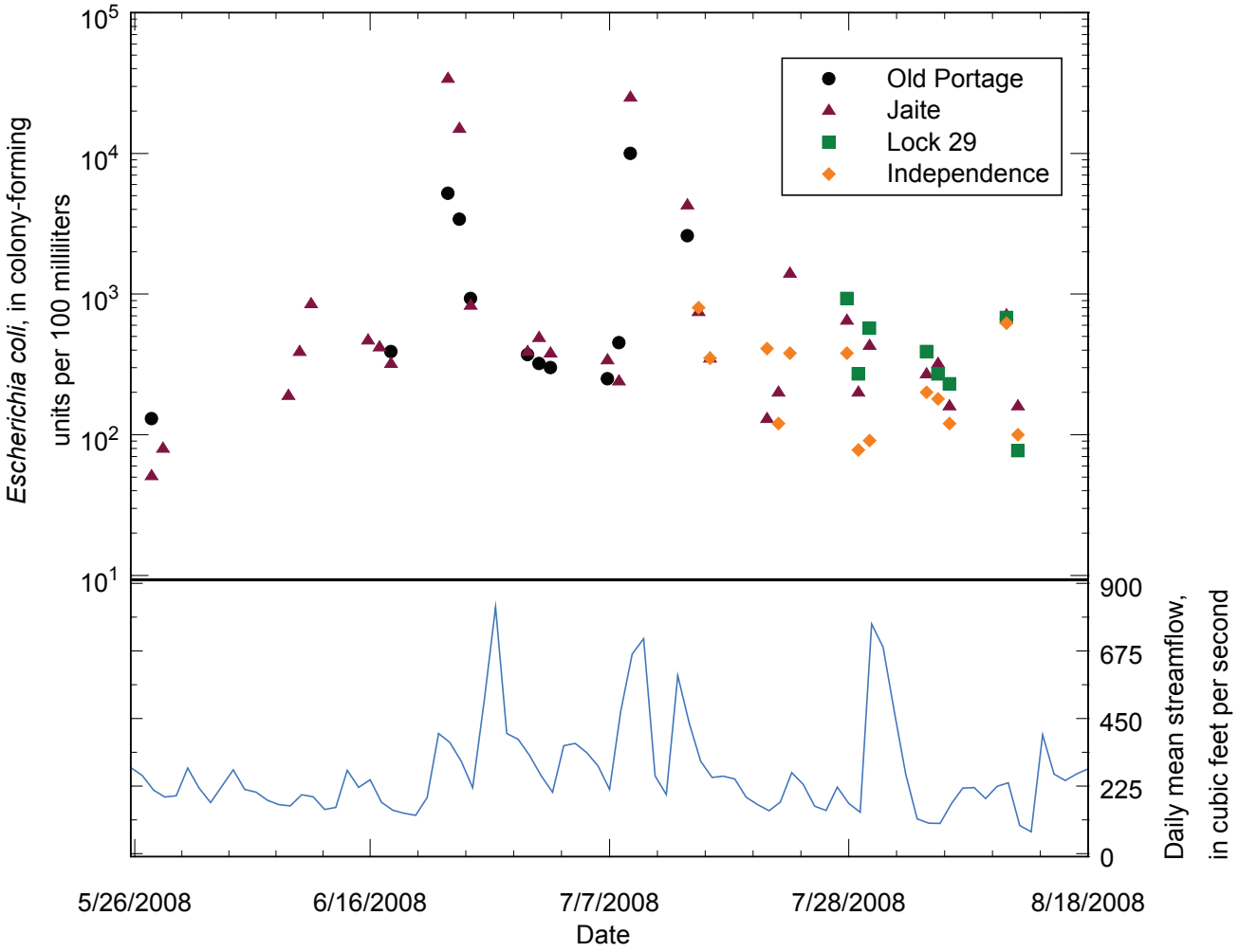

Figure 2. *Escherichia coli* concentrations at four sites along the Cuyahoga River during the recreational season (May through August) of 2008. Daily mean streamflow measured at one site (Old Portage) also is shown.

than 450 ft^3/s, as observed at Old Portage) prior to the start of sampling at Lock 29 and Independence (fig. 2). These events were associated with high *E. coli* concentrations. Although sampling at Lock 29 and Independence included one high-streamflow event, concentrations were not as high during this event as during previous ones.

At Jaite and Old Portage, correlations between log_{10}-transformed concentrations of *E. coli* and log_{10}-transformed turbidity, rainfall total for the previous 24 hours, and gage height at the time of sampling were statistically significant (table 3). The relation between turbidity and *E. coli* at Jaite had a higher Pearson's r correlation coefficient than the other relations examined, suggesting that turbidity is the best predictor of recreational water quality than the other variables at this site. At Lock 29 and Independence, correlations between concentrations of *E. coli* and turbidity or gage height (Independence only) were significant, but rainfall was not significantly related to *E. coli* concentrations at these sites.

Validation of Turbidity-Based Predictive Model

A turbidity-based model developed from data collected during 2004 through 2007 for the Jaite site (Brady and others, 2009) was validated by using the 2008 data presented in this report. Of the 31 samples collected at Jaite, 24 samples, or 77 percent, were correctly predicted in terms of being above, at, or below the WQS (fig. 3) as measured by the culture-based method. The model generally underpredicted concentrations when measured *E. coli* concentrations were greater than 1,000 CFU/100 mL but still correctly predicted these concentrations as exceedances of the WQS. Five samples were "false negatives," meaning the *E. coli* concentrations in the samples exceeded the WQS, but the model predicted these sample concentrations below the WQS. The remaining two samples were "false positives," meaning the model predicted *E. coli* concentrations above the WQS, but the actual concentrations were below the WQS.

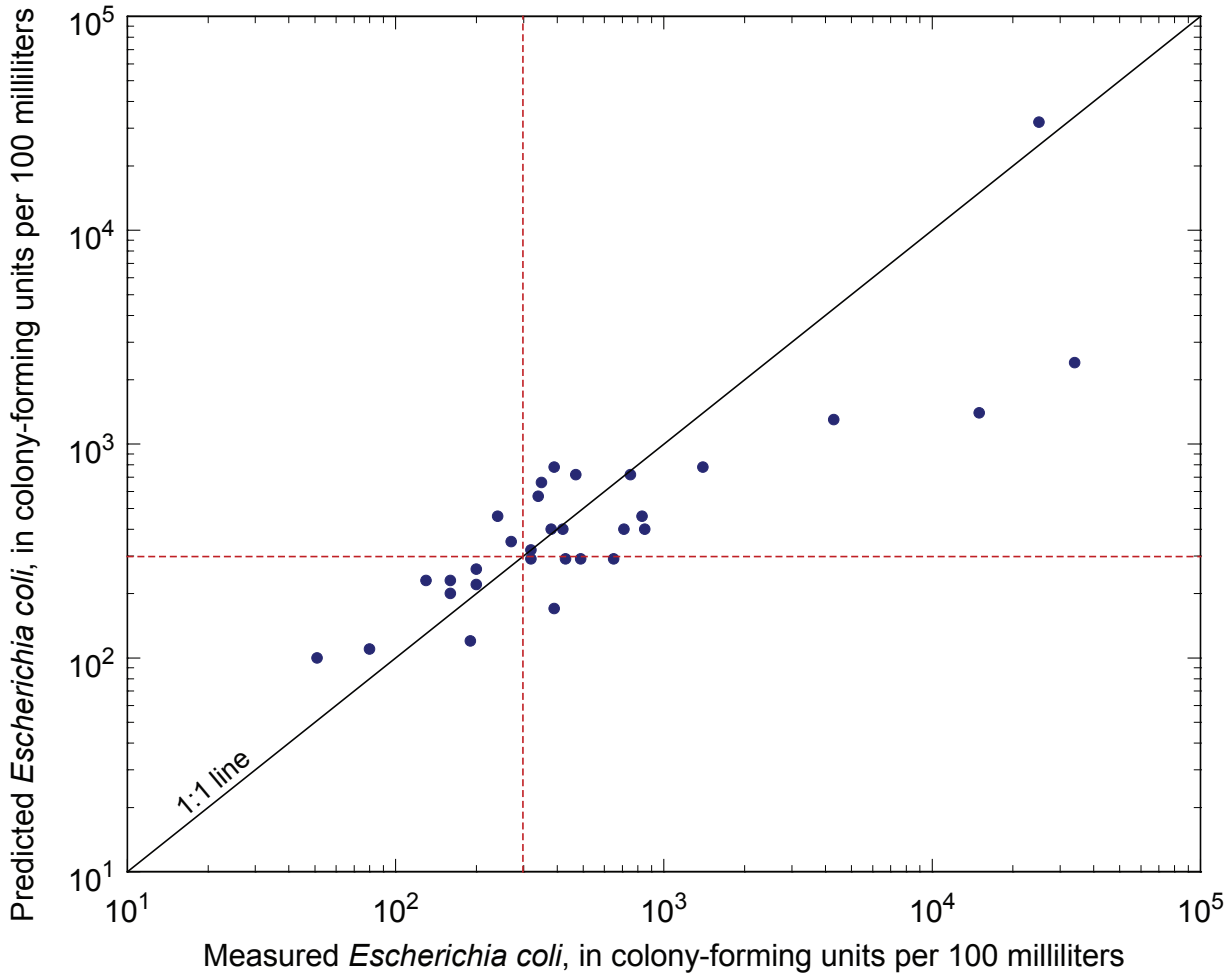

Figure 3. *Escherichia coli* concentrations in water samples collected from the Cuyahoga River at Jaite (Brecksville), Ohio, compared to predicted concentrations from a simple linear regression model based on turbidity. The red dashed lines indicate Ohio's single-sample standard for primary-contact recreation (298 colony-forming units per 100 milliliters).

Table 3. Relations between log10-transformed *Escherichia coli* concentrations and environmental variables in the Cuyahoga River during the recreational season (May through August) of 2008, Cuyahoga Valley National Park, Ohio.

[Rainfall, the total rainfall during the previous 24 hours prior to sample collection; --, no data available]

Site name	Number of samples	Pearson's correlation coefficient, r (p-value)		
		Log_{10} turbidity	Gage height	Rainfall
Old Portage	12	0.92 (<0.0001)	0.78 (0.0026)	0.71 (0.0102)
Lock 29	8	.89 (0.0032)	--	.18 (0.6666)
Jaite	31	.86 (<0.0001)	.67 (<0.0001)	.57 (0.0008)
Independence	13	.67 (0.0126)	.80 (0.0011)	.35 (0.2440)

The concentrations predicted by the model developed for the Jaite site were compared to measured *E. coli* concentrations at the other three sites sampled. The Jaite model correctly predicted exceedances or non-exceedances of the WQS in 75 percent of the samples collected at Lock 29 and Independence and in 83 percent of the samples collected at Old Portage. Further testing would need to be completed prior to use of the Jaite model for predictions elsewhere along the river.

Ongoing Work

During the recreational season of 2009, samples were collected at Jaite four times per week and predicted concentrations of *E. coli* for this site were posted on the Ohio Nowcast website (*www.ohionowcast.info*). Samples were also collected at Lock 29 and Independence four times per week to further examine the relations between the actual concentrations at these sites, as determined by the culture-based method, and the predicted *E. coli* concentrations at Jaite. This research is planned to continue through the recreational season of 2010.

Summary

The U.S. Geological Survey, in cooperation with Cuyahoga Valley National Park and Ohio Lake Erie Commission, completed a study during the recreational season (May through August) of 2008 to validate a regression model used for predicting recreational water quality in the Cuyahoga River within the Cuyahoga Valley National Park.

Within the Cuyahoga Valley National Park, water-quality of the Cuyahoga River was examined during the recreational season (May through August) of 2008. Concentrations of *E. coli* were measured three days per week at a site centrally located within the park (Jaite) and at three other sites on the river. Environmental and water-quality measures were compared to *E. coli* concentrations. At all four sites, relations between turbidity and *E. coli* concentrations were statistically significant. Relations between *E. coli* concentrations and gage height were statistically significant at the three sites where gage height data were available. Rainfall amounts were significantly correlated to *E. coli* concentrations at Jaite and Old Portage, a site just upstream from the park, but not at the other two sites.

A turbidity-based simple linear regression model, developed from data collected during the recreational seasons of 2004 through 2007, was validated during 2008. *E.coli* concentrations at Jaite were compared to predicted *E. coli* concentrations from the model. The model correctly predicted exceedances or non-exceedances of Ohio's single-sample standard for primary-contact recreation (WQS) in 77 percent of the samples collected at Jaite. Further, predicted concentrations based on turbidity measured at Jaite were compared to measured concentrations at the other three sites. The predicted concentrations agreed with the measured concentrations (above, at, or below the WQS) between 75 and 83 percent for the samples collected at the other sites.

Future work at the Cuyahoga Valley National Park is expected to include posting predicted concentrations on the Ohio Nowcast website and further study of using the turbidity model to predict exceedances or non-exceedances of the WQS at other sites on the river.

Acknowledgements

Donald J. Doyle III is thanked for his tireless assistance with sample collection and analysis.

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